

ESD Design Guidelines for Systems and Circuits

Presented By

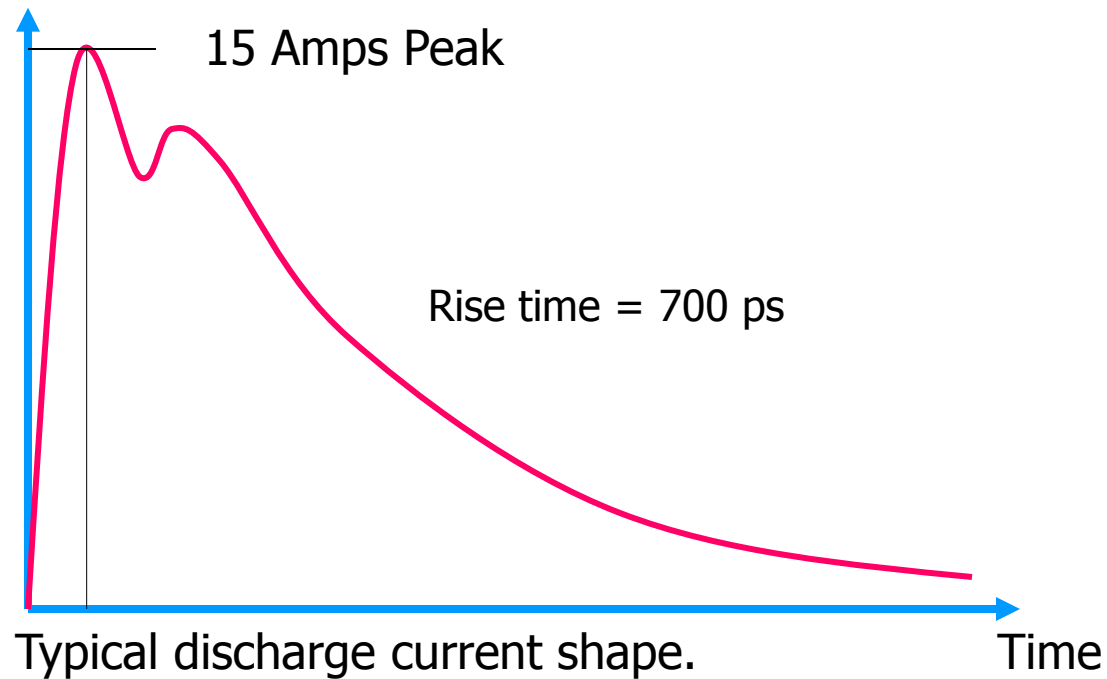
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Types Of Susceptibility

- ESD at the system level is an EMC requirement.
- Susceptibility can be classified based on:
 - (a) Bandwidth:
 1. Broadband: Examples: ESD, Surge, EFT.
 2. CW or NB: Examples: Radiated, Conducted RF.
 - (b) Phenomenon: ESD, Lightning, RF, EFT.

ESD At System Level



- ESD is not static.
- It tests the system for susceptibility performance.
- It assures prevention of data loss during operation.

ESD Characteristics

- Broadband Test:
 - ESD is a broadband test determined by the rise time.
 - 700 p.s. corresponds to about 500 MHz in frequency.
- Statistical Results:
 - The waveform can change from one discharge to the next without any change in the test set up.
Therefore, the test is repeated for each polarity at each voltage.

ESD Characteristics (Continued)

- Voltage Interpolation Invalid.
 - The test voltage is increased in steps of 0.5 kV*.
- Environment Dependent.
 - The results depend on temperature and humidity.

*This also reduces the probability of equipment damage.

Design Techniques

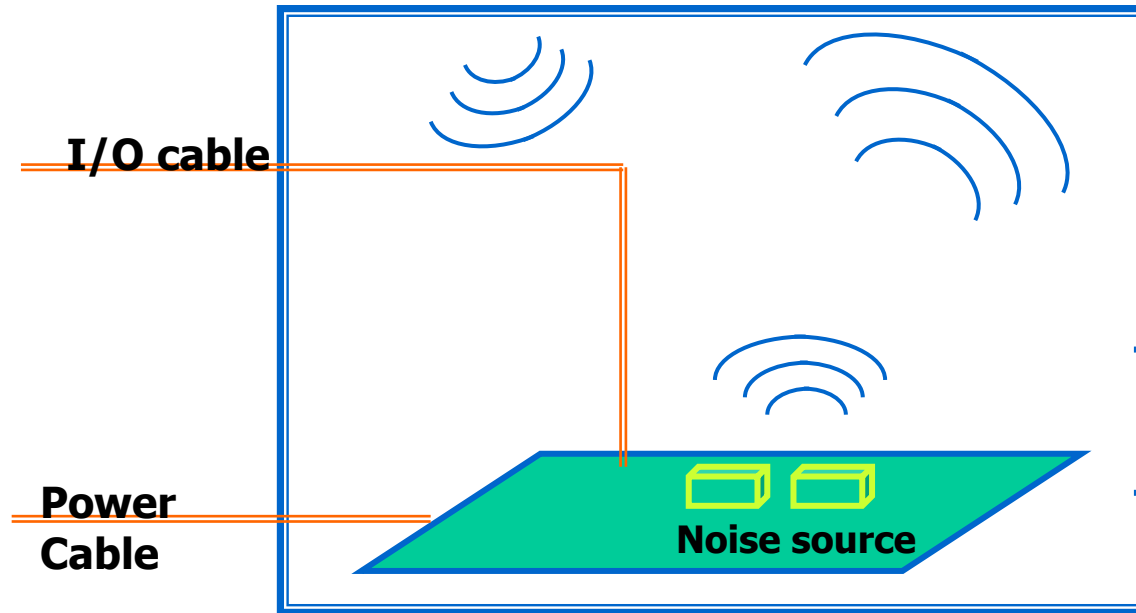
- **Path for the noise** to get into the system or circuit is usually the same as for it to get out. Therefore, the techniques for ESD control are similar to those for emission control. Exceptions:
 1. Emissions not possible if the frequency is not generated.
 2. Immunity difficult if signals are small, emission compliance easier.

ESD is Noise Getting In

- In a system noise propagation occurs at two levels.
- (1) At the system enclosure and (2) at circuit (PCB).
- The two approaches are complimentary and used as necessary.

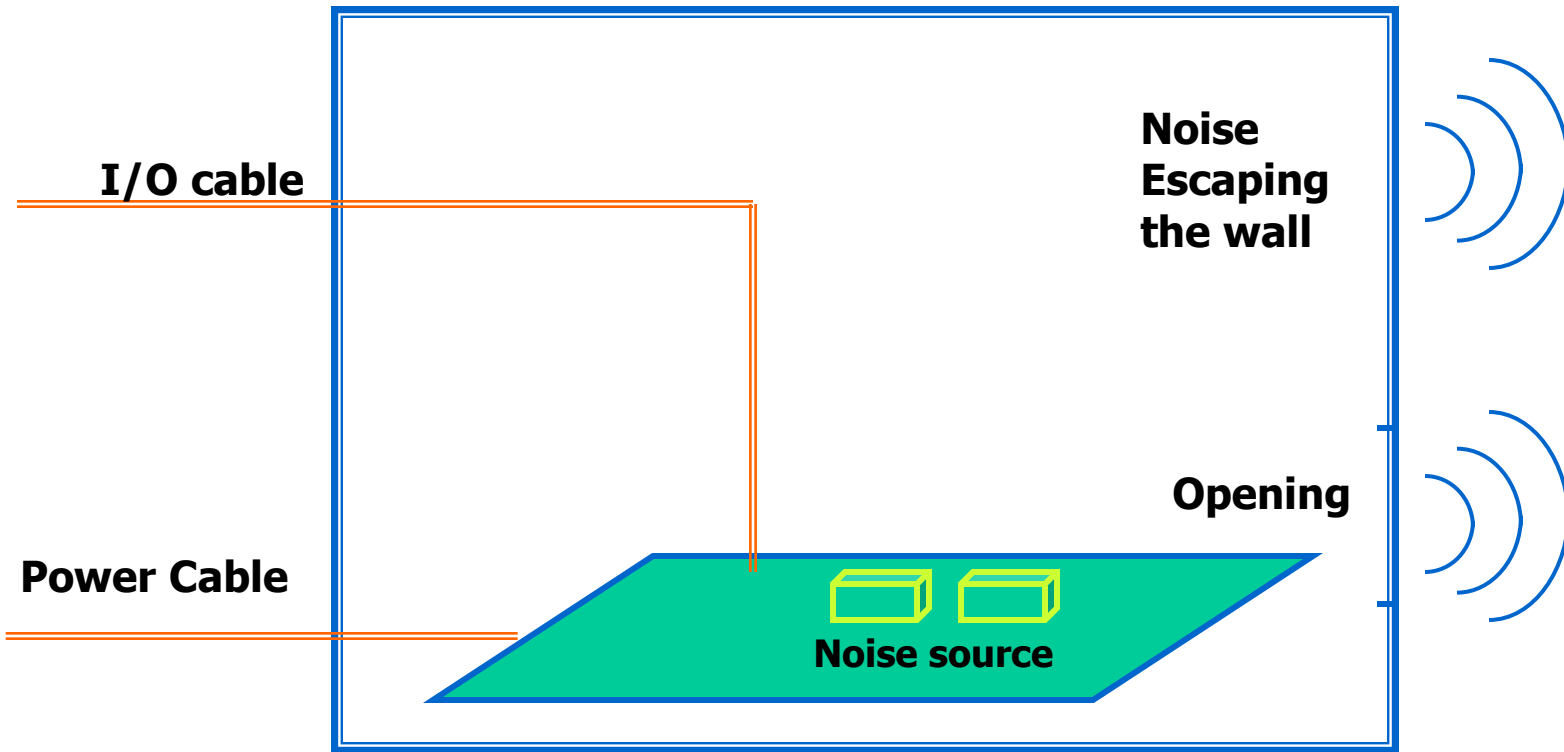
- The faster, higher bandwidth digital circuits are more susceptible to ESD at system level.

Noise Propagation (In or out)



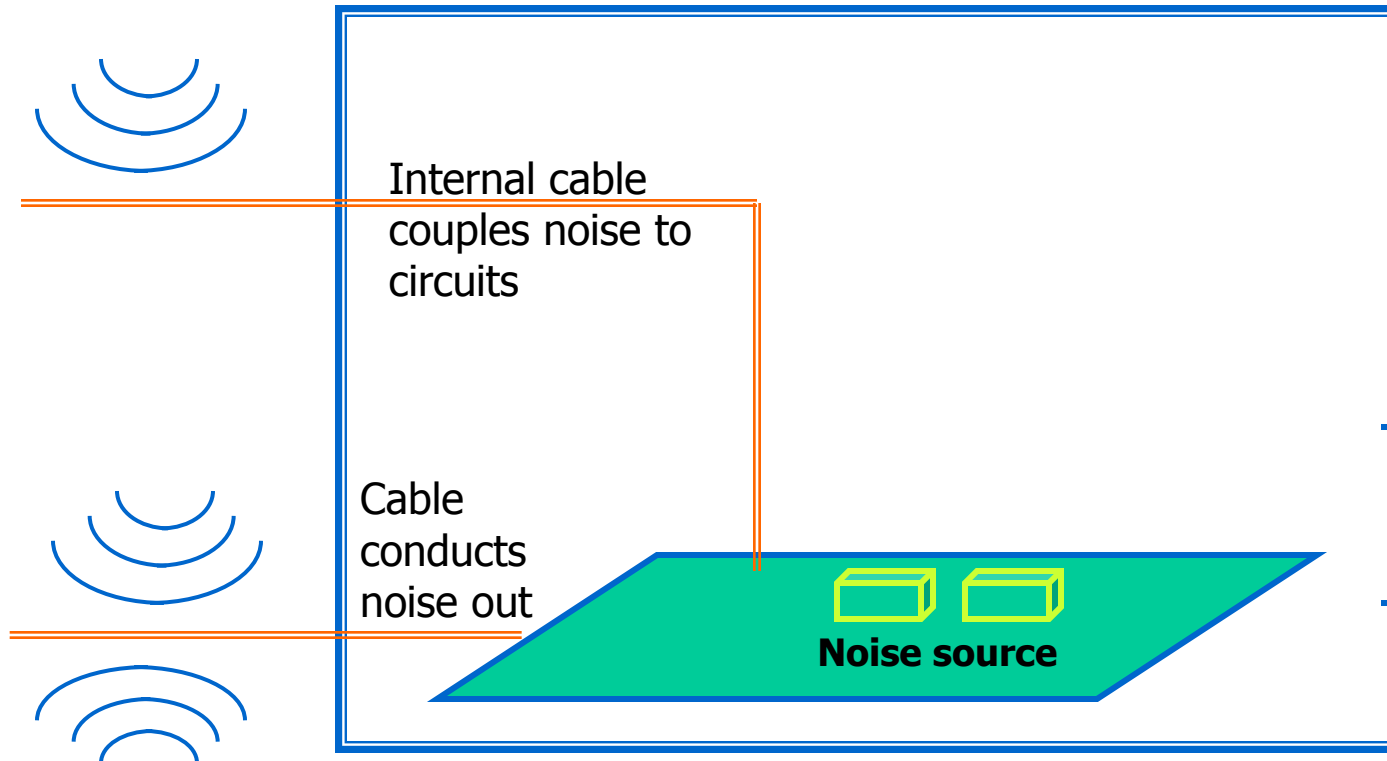
- In a system the metal enclosure (shield) prevents noise from getting in or out.

Noise Propagation



- Noise can still escape (or come in) through the walls and it can leak through the seams and openings.

Noise Propagation On Cables



- Cables allow the noise
 - To propagate into the system
 - To propagate out of the system

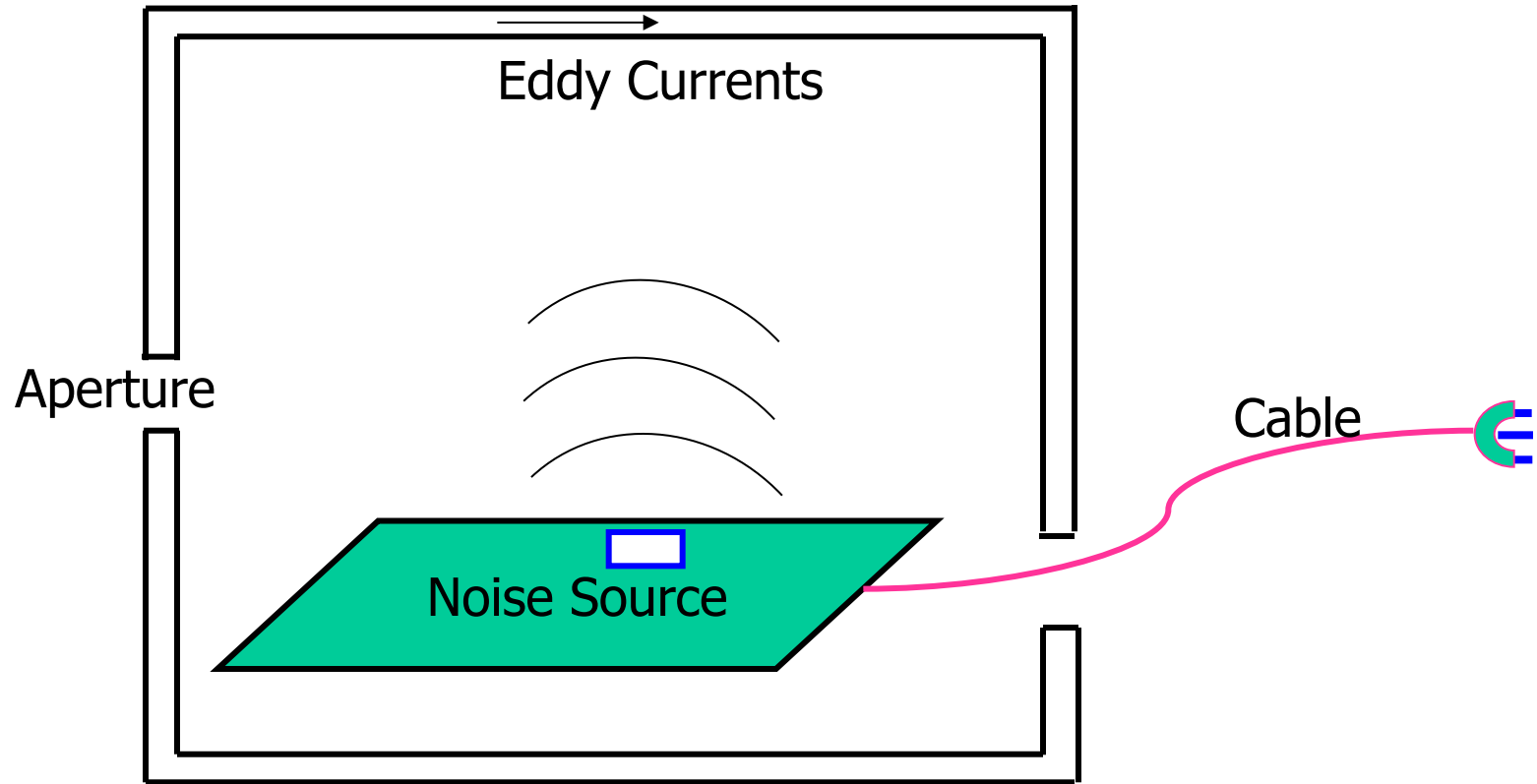
Two Tests Recommended For ESD

- Direct discharge test (air and contact).

It simulates ESD event for system. It also verifies some protection against radiated field susceptibility.

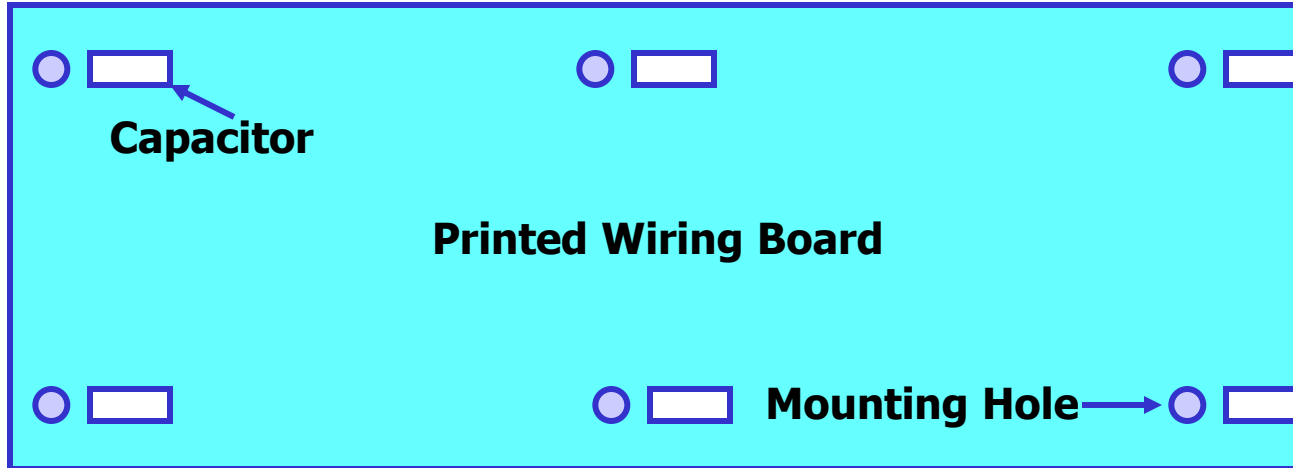
- Indirect/ radiated ESD.
- It is used for system in which direct discharge can not be caused. It simulates ESD event for systems with **plastic enclosure**.
- So such systems are better or immune?

Absorption Loss



- Absorption loss occurs due to conversion of electromagnetic energy into heat.

Chassis Ground



- A direct low impedance connection to chassis is important.
- A low cost approach is to use the mother board mounting pads.
- Capacitive connection can be made to the signal ground at several points if single point ground is to be maintained.
- The effective capacitor leads must be short.

ESD Design

- So enclosure and PCB techniques can be used together.
- ESD is a broadband electromagnetic event and all design principles (of shielding, filtering and grounding used to control noise) are also applicable for ESD.
- Single reference grounding may be used since ESD has low as well as high frequency energy present.
- Susceptible signal line can be filtered using an RC network at the input (if permitted by the signal bandwidth).

Printed Wiring Board

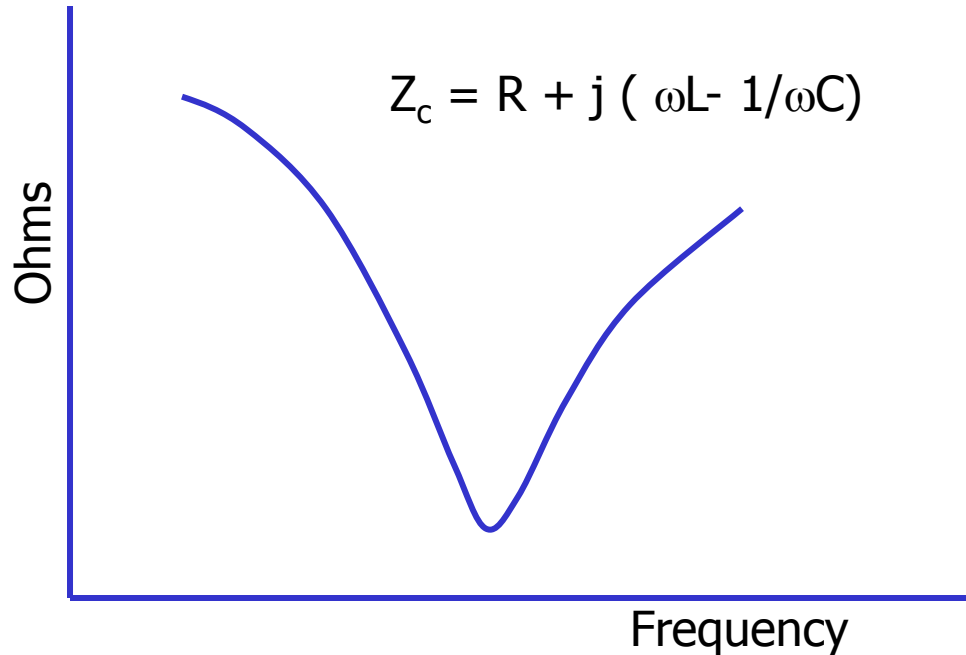
- In electronic systems, most of the circuit is located on the PWB. Therefore, controlling noise on the PWB is also important.
(2nd level of defense?)
- On the PWB the noise is generated /injected into:
 1. Power and Ground circuits.
 2. The signals.
- Grounding scheme on PWB includes ground as well as power. They must be at the **same RF potential**. How?

Grounding Schemes For PWB

- AREA FILL METHOD - Fill up all open areas with ground trace.
- POWER AND GROUND GRIDS - Design the PWB layout with carefully planned power and ground distribution grids. (5 MHz).
- GROUND AND POWER PLANE - Multi-layer PWB with full layers for power distribution. (10 MHz).
- CONTROLLED IMPEDANCE - Utilize the ground and power planes to form transmission lines.

In all cases, ground and power must have **adequate decoupling** to be at the same RF potential.

Capacitor Resonance

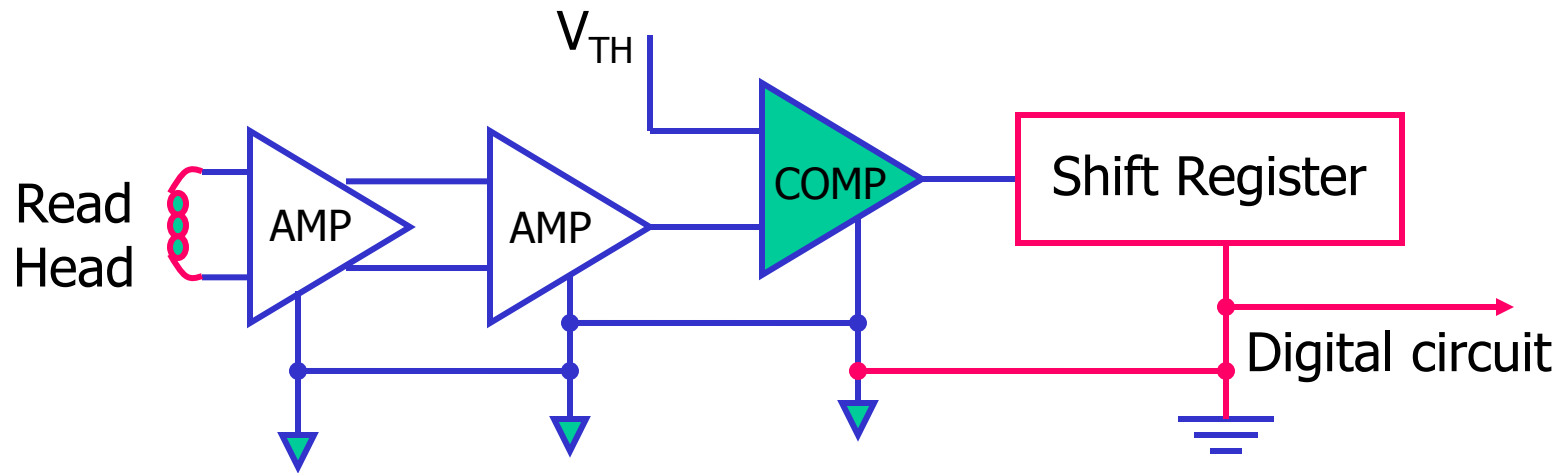


- The useful frequency range of a capacitor is limited up to its resonance frequency.
- It is dependent on material, lead length and internal structure.

Single Point Or RF Grounding

- Grounding scheme is chosen according to requirements.
- The RF and AF requirements are not contradictory.
- Use the following guidelines:
 - Control the operating bandwidth used - this limits electromagnetic emissions and susceptibility.
 - When low (audio) frequency **and** high (RF) frequency protection is required, use multi- point AC ground with only one DC connection.
 - Separate grounds according to signal levels - since induced noise can affect signal only if ground loop is part of the signal circuit.

Ground and Signal Go Together

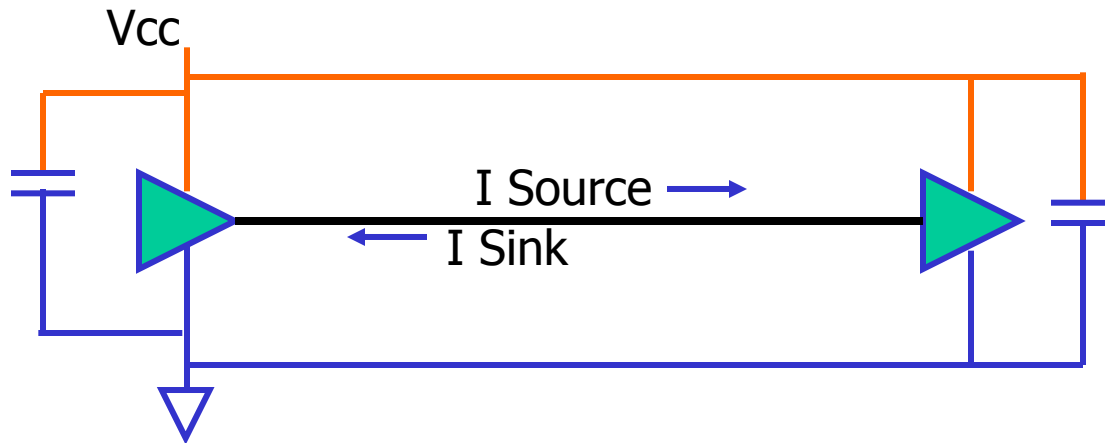


- Keep **ground with the signal** when connecting different circuits.
- **Ground is the return path** for the signal and power current.
- This rule is very important - when we break a ground loop.

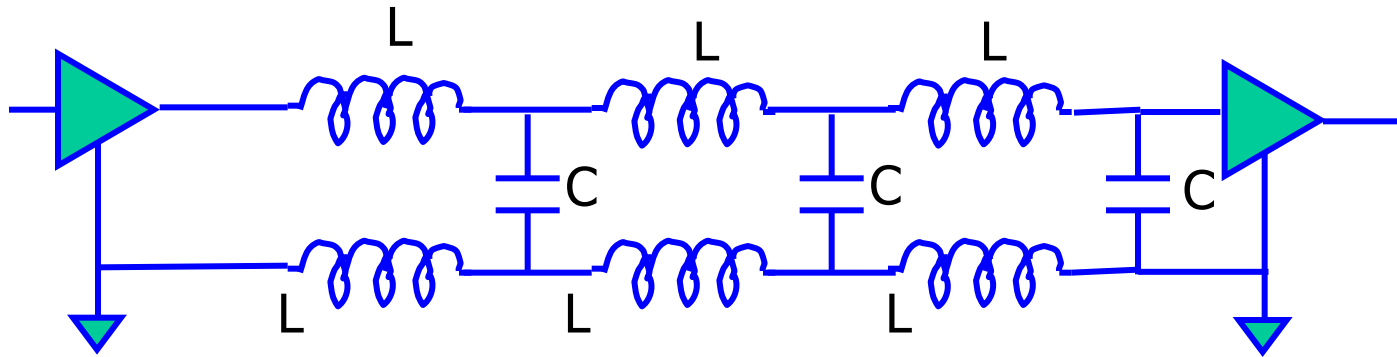
Signal Circuits

- Noise into/out of signals: The signal and return traces can act as rod (voltage) and loop (current) antennas.
- The length and loop areas of these antennas must be controlled on the PCB and in the system inter-connect.

However, the best approach is using **transmission lines**.

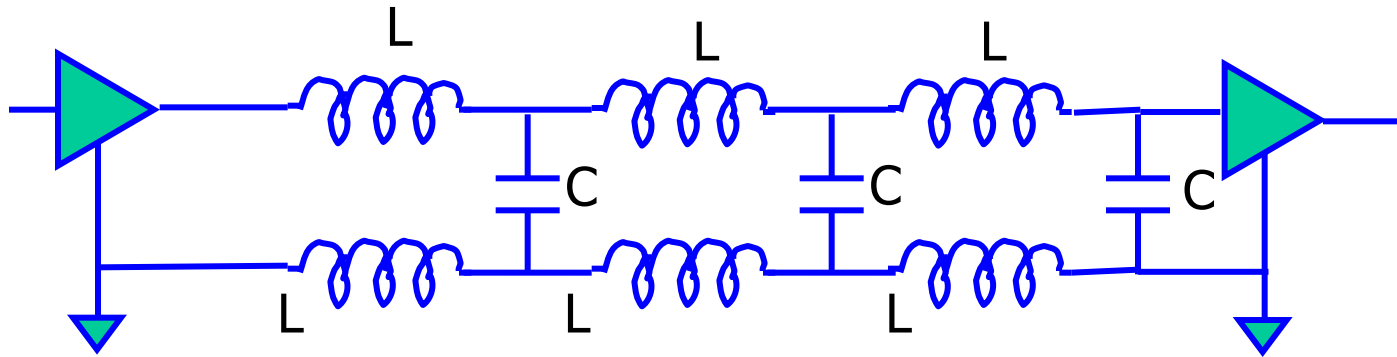


Important Features



- **Dedicated space** for traveling electromagnetic energy.
- **Mutual coupling** between signal and return path.
- Eliminate cross-talk if no coupling to other traces.
- But transmission lines in practice are not ideal. The storage space for traveling wave may not be exclusive for each signal, so the cross-talk is not totally eliminated.

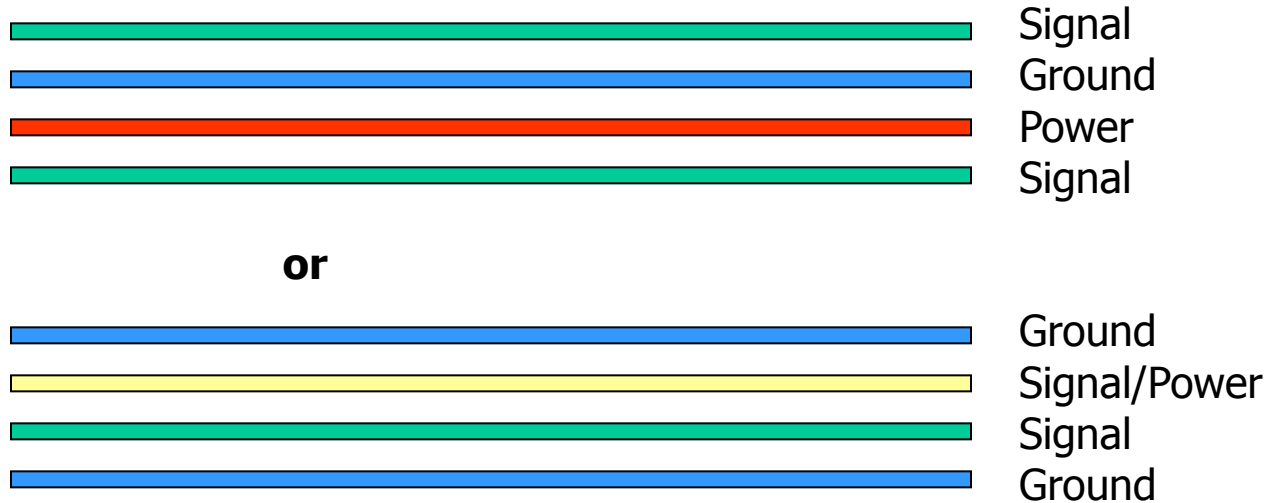
Transmission Line (Ideal)*



- Distributed parameters, and characteristic Impedance.
- Reflections can be controlled by controlling the impedance.

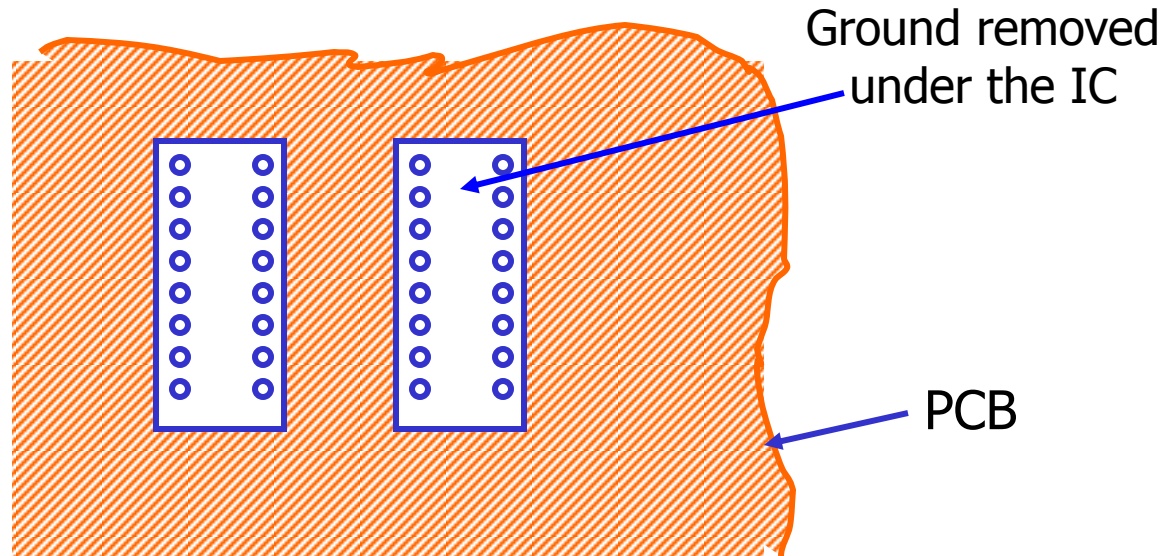
* Because no resistive loss shown.

Layer Stacks For Four Layer PCB



- Would it help to put the ground layers on the outside surface?
- How useful are high frequency signals embedded into the ground and power planes? Plus some more mistakes

Ground Near Integrated Circuits



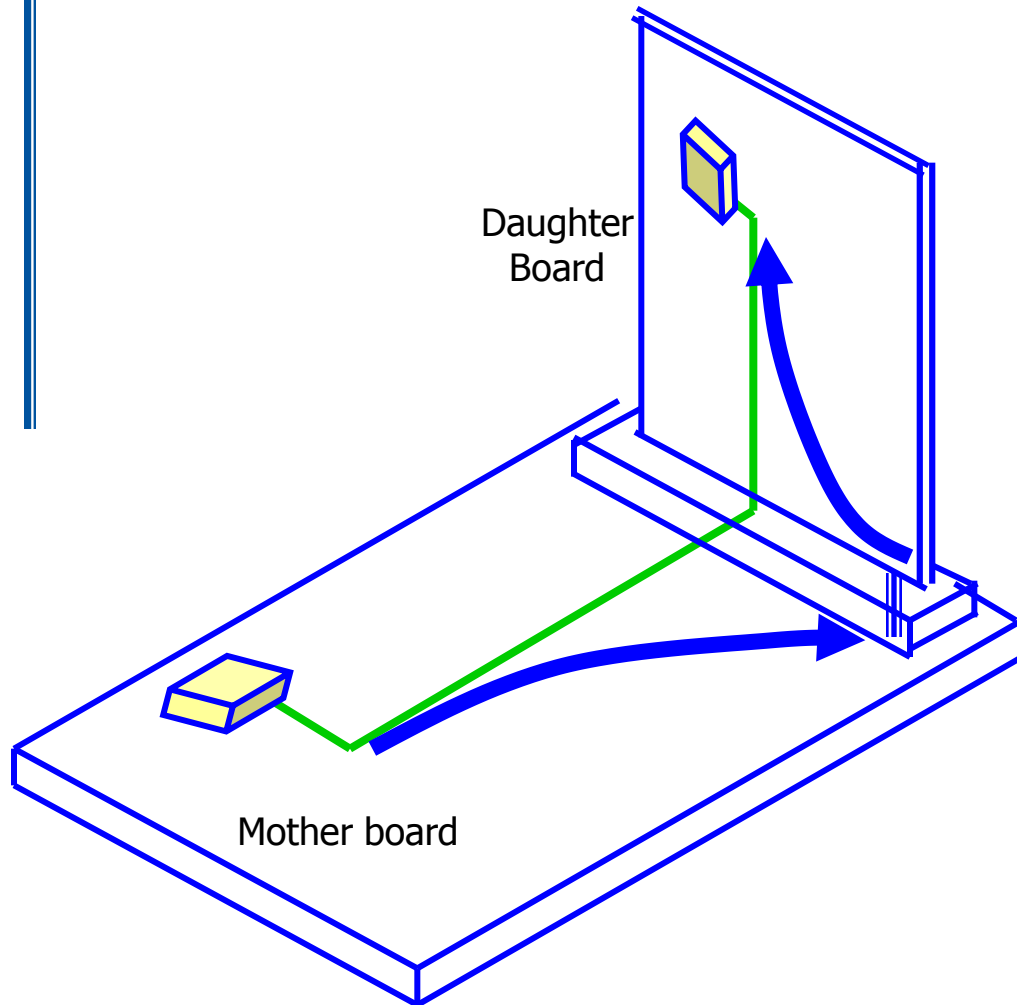
- The ground plane should not be removed underneath an IC or even a row of pins. If any large area or length of ground plane is removed, the usefulness of the ground plane is diminished.

Poor Ground Plane Design

- Ground along the rows of pins is removed for convenience.
- Any cut or opening created in ground plane is a break in the transmission line.
- Can a large loop exist even with a solid ground plane?

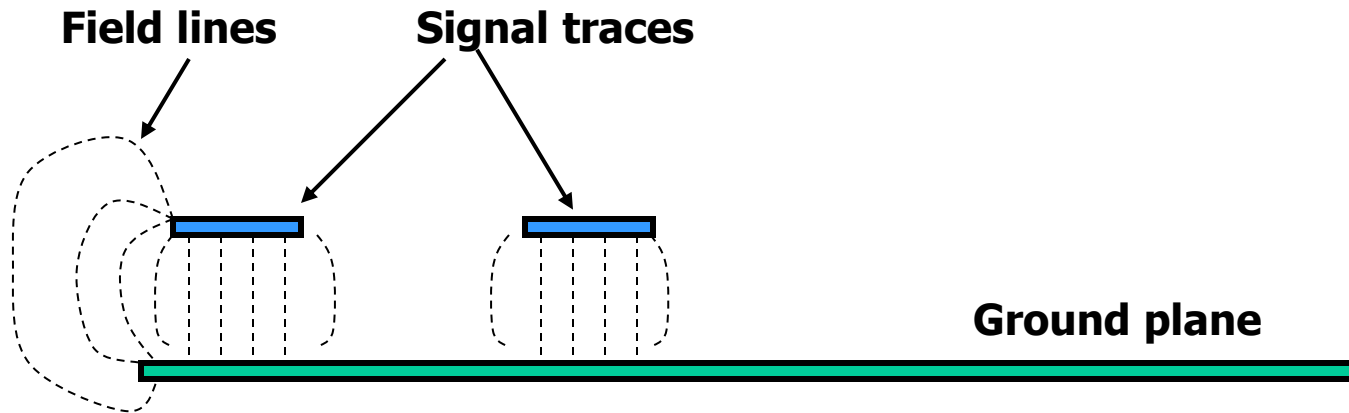


Large Loops In Signal Return Paths



- Even with a ground plane in the PWB, a large loop in the signal path can exist.
- A return pin far away from signal pin will cause a loop.
- Large loops in signal return paths can be avoided by using distributed grounds.

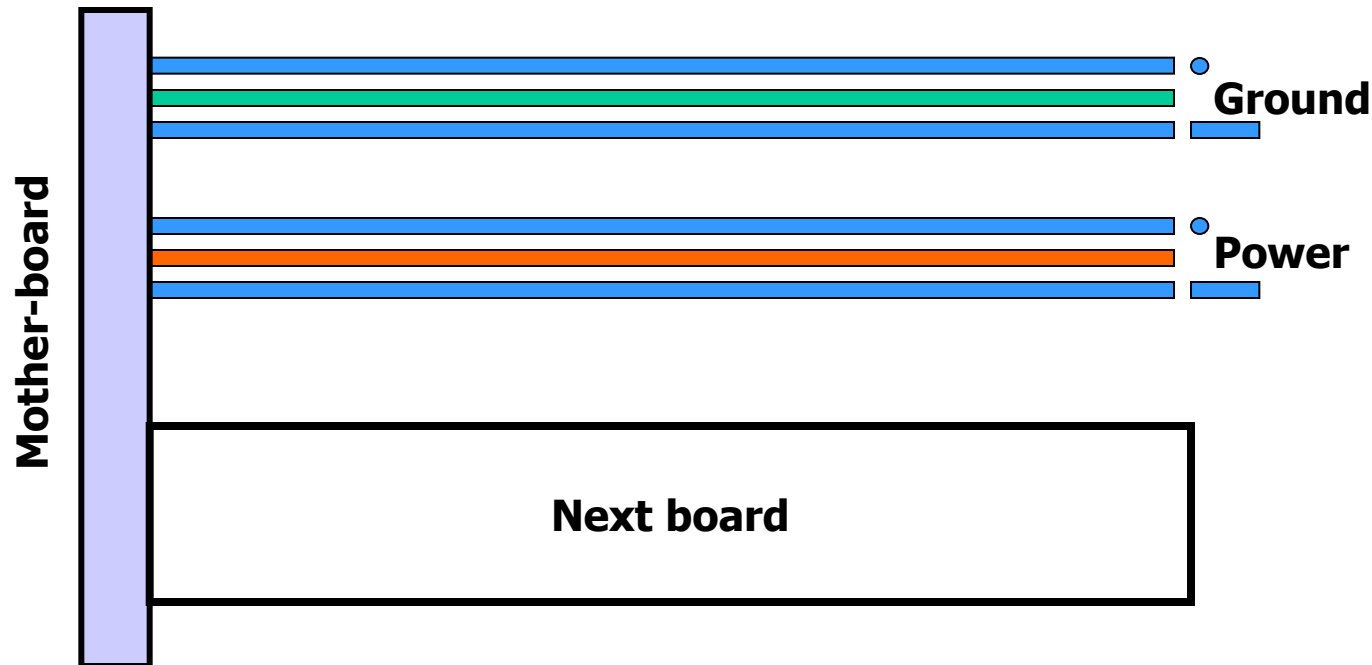
Layout Near Board Edge



- Fringing near edge changes the characteristic impedance of the signal.
- This can result in ringing and additional radiation for high frequency signals.
- The advantages of the ground plane may be lost completely, if traces are laid outside the ground plane boundary.

Six Layer PCB

- Alternate layers do not have to be a power or ground layer.
- The signals must form transmission lines with planes.
- Layer 3 to 4 distance must be much larger than other layers.



Summary

- Use optimized system level protection of case shielding with cable shielding, if available.
- Use all circuit level protections that transmission line circuits can provide.